Lecture 15

ASSIGNMENT

SEND ME A PARAGRAPH ABOUT YOUR PROJECT TOPIC

TODAY

APPLICATIONS OF PARALLEL TRANSMIT
- PULSE DESIGN
- POWER AND SAR
- PARALLEL TRANSMIT VS PARALLEL RECEIVE

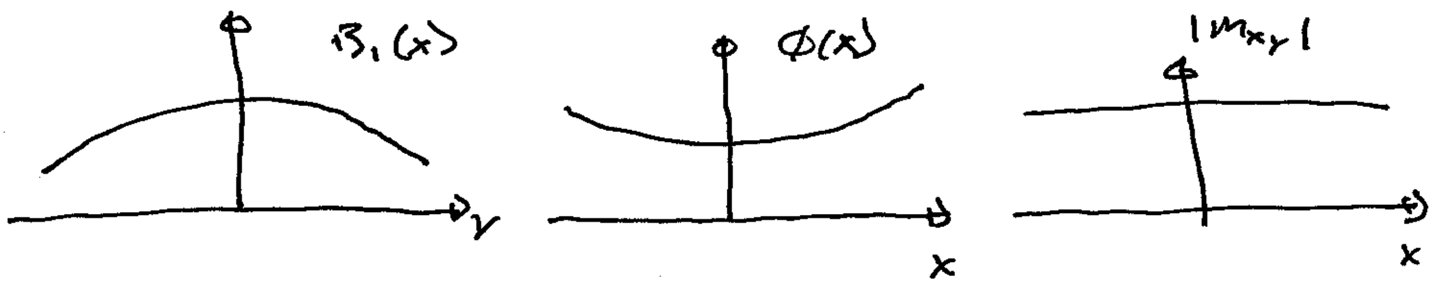
B_1 MITIGATION

B_1 SHIMMING MOST COMMON PARALLEL TRANSMIT APPLICATION ⇒ FLATTEN OUT TRANSMIT FIELD

NEXT MOST COMMON IS B_1 CORRECTION OR MITIGATION

GOAL IS TO PRODUCE UNIFORM FLIP ANGLE EVEN THOUGH B_1 VARIES SPATIALLY

<u>BASIC IDEA</u> USE A SPATIALLY SELECTIVE PULSE



SPATIALLY VARYING RF FIELD

SPATIALLY VARYING "FLIP ANGLE"

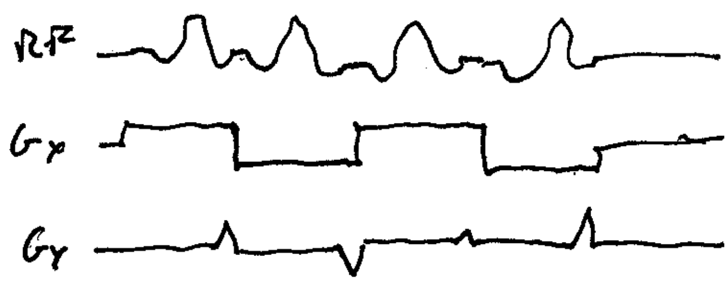
EXCITED MAGNETIZATION

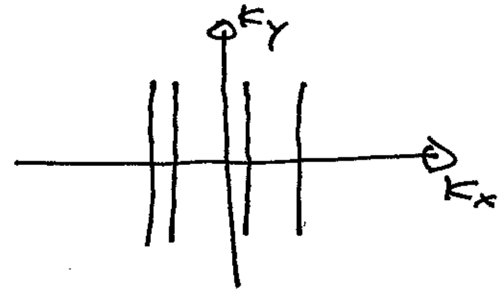
CONCEPTUALLY, WE COULD USE ANY OF OUR 2D PULSE DESIGN METHODS (OR 3D!)

IN PRACTICE, WE WANT SOMETHING VERY SHORT AND SIMPLE

SPOKES AND POINTS PULSES

SPOKES PULSE ARE A SEQUENCE OF 1D PULSES SEPARATED BY BLIPS



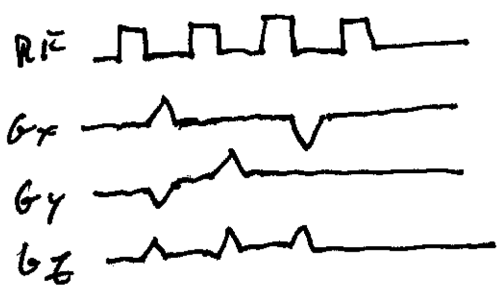


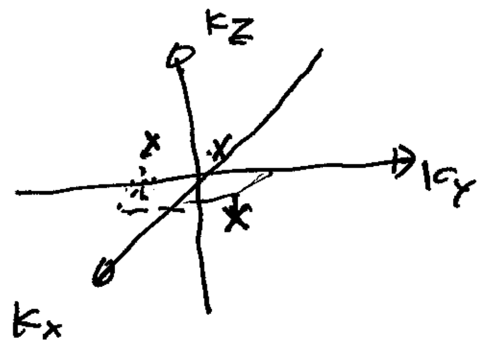
JUST A FEW LINES IN SPATIAL FREQUENCY (LOW)

SPACINGS AND PULSE PROFILES OPTIMIZED

ONLY A FEW ms LONG

POINTS PULSES EVEN SIMPLER





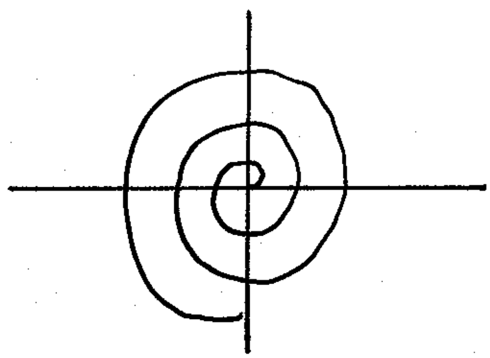
JUST A FEW SPATIAL FREQUENCIES ARE EXCITED. AMPLITUDES, PHASES, AND SPATIAL FREQUENCIES ARE ALL OPTIMIZED.

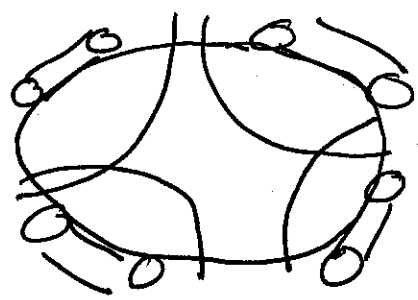
LARGE FLIP ANGLE PULSES

SO FAR, SMALL-TIP-ANGLE PULSES

PULSES BASED ON INHERENTLY REFOCUSED
PULSES ARE LINEAR IN ROTATION ANGLE

SAME HOLDS FOR PARALLEL EXCITATION





EACH COIL PRODUCES ROTATION ABOUT A
common AXIS

ROTATIONS ADD

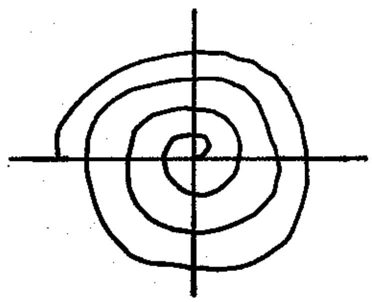
LIMITATIONS

1) DYNAMIC RANGE

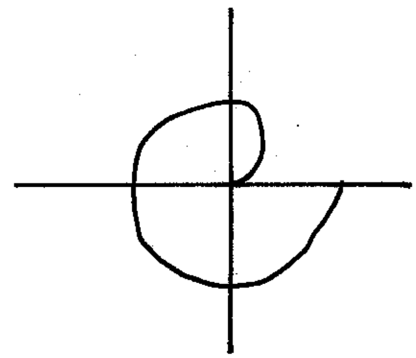
NEAR COIL, LARGE ROTATION PER
GRADIENT CYCLE

VIOLATES SMALL ROTATION APPROXIMATION

2) HIGH ACCELERATION



ORIGINAL TRAJ



4X ACCELERATED TRAJ

ORIGINAL TRAJECTORY WELL APPROXIMATED BY CIRCULAR RINGS, INHERENTLY REFOCUSED SUBPULSES

⇒ LINEAR IN ROTATION

ACCELERATED TRAJECTORY NOT WELL APPROXIMATED

⇒ NOT LINEAR IN ROTATION

<u>OTHER TRAJECTORIES</u>

PULSES THAT ARE NOT LINEAR IN ROTATION ARE HARDER TO DESIGN

<u>SPECTRAL-SPATIAL / EPI</u>

GENERALLY DONE USING OPTIMIZATION

RF POWER AND SAR

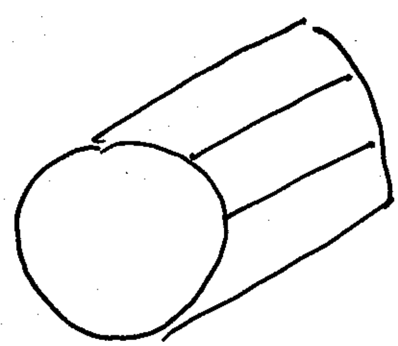
MAJOR MOTIVATION FOR PARALLEL TRANSMIT IS POTENTIAL TO REDUCE SAR

IMPORTANT FOR
- HIGH FIELD
- INTERVENTIONS

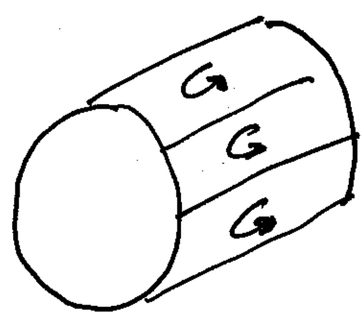
COMPLEX PROBLEM, MANY ISSUES
- SAR DISTRIBUTION DIFFERS FROM B_1
- SMALLER EXCITATION VOLUME REDUCES SAR
- DIFFERENT PULSES

NOTHING FUNDAMENTAL ABOUT PARALLEL TRANSMIT THAT REDUCES SAR

SAME VOLUME, B_1 PRODUCES SAME SAR



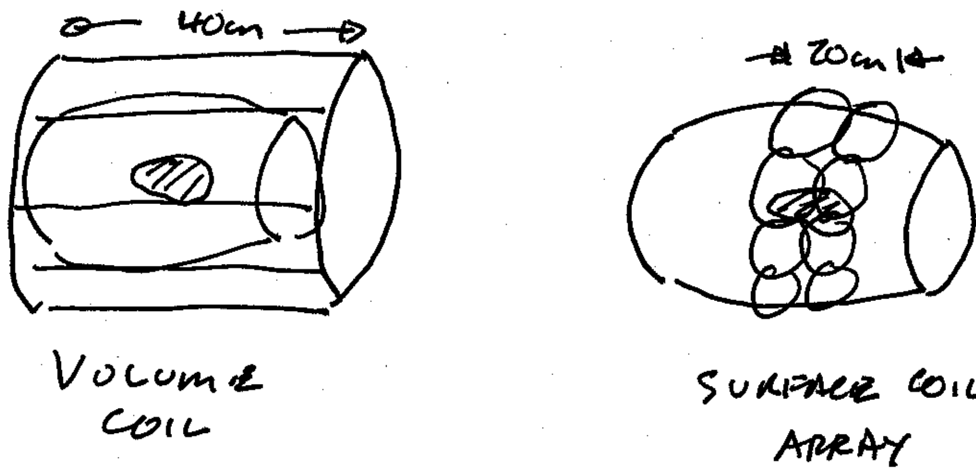
BIRDCAGE



RECTANGULAR ARRAY

PRODUCES SAME FIELDS, SAME SAR

PARALLEL TRANSMIT REDUCES SAR BY REDUCING EXCITATION VOLUME



SAR GOES DOWN FASTER THAN LINEARLY

DETAILED DEPENDENCE IS COMPLEX, DEPENDS ON COIL GEOMETRY AND CONDUCTIVITY OF SUBJECT

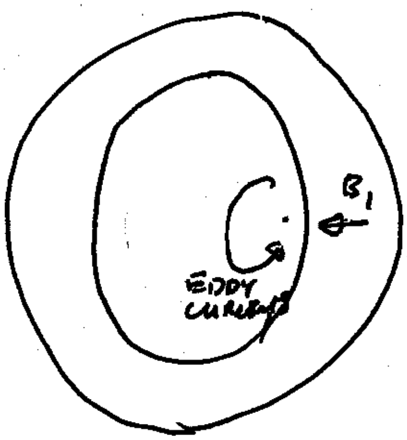
SAR AND B_1 CAN HAVE VERY DIFFERENT DISTRIBUTIONS

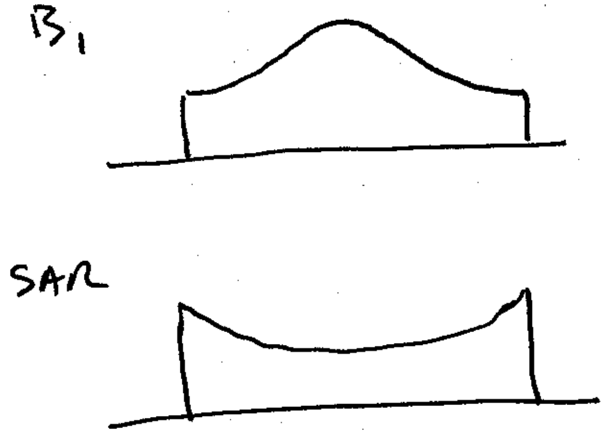
SAR DUE TO E FIELD

$$SAR \sim \int_t \int_V \sigma(\underline{r}) \left| E(\underline{r},t) \right|^2 dV\, dt$$

RF EDDY CURRENTS IN SUBJECT

EXAMPLE HEAD COIL AT 7T

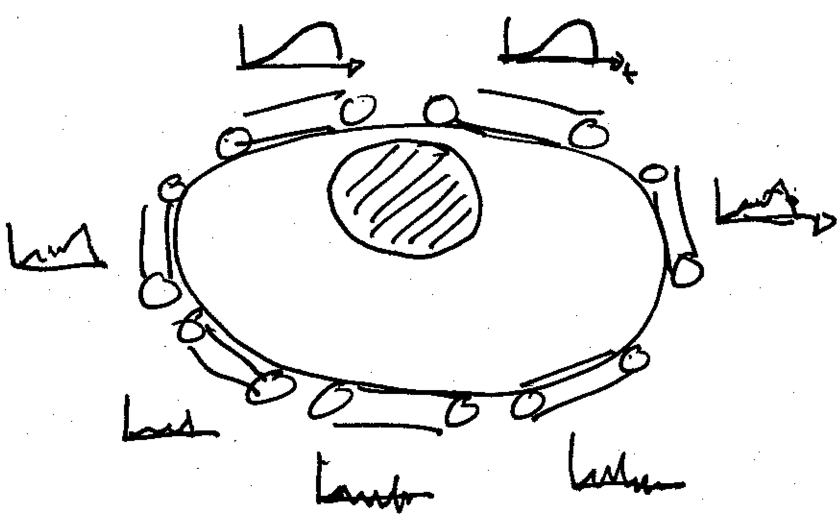




EDDY CURRENTS OPPOSE B_1, TEND TO SHIELD INTERIOR

COMPUTING SAR REQUIRES FULL 3D EM SIMULATION

PULSE DESIGN ALSO EFFECTS SAR



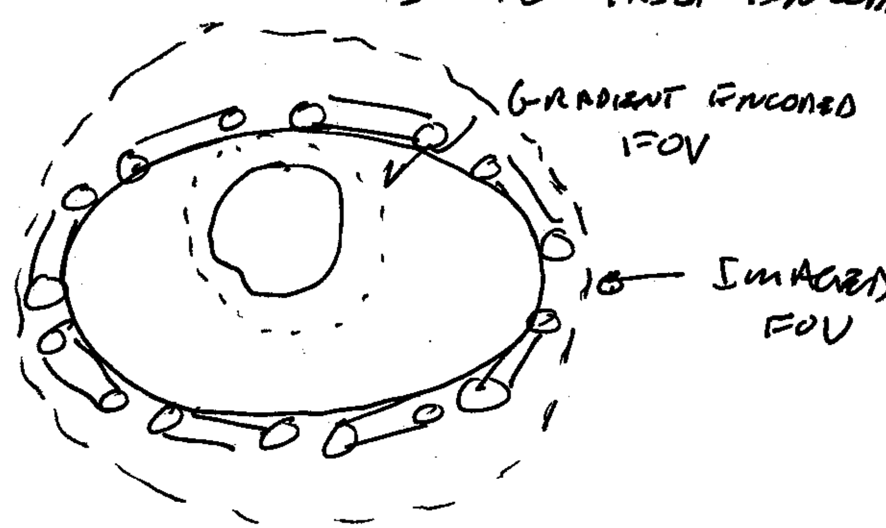
MOST EXCITATION DUE TO CLOSER COILS

PARALLEL RECEIVE VS PARALLEL TRANSMIT

BOTH CAN BE USED TO ACCELERATE IMAGING

PARALLEL RECEIVE

USE COIL SENSITIVITIES TO HELP ENCODE



GRADIENT ENCODING HAS INADEQUATE FOV

USE SENSITIVITIES TO SORT OUT ALIASING

SNR LOSS DUE TO

- REDUCED SCAN TIME
- COIL SENSITIVITIES NOT ORTHONORMAL BASIS

IF SENSITIVITIES ARE COLLECTED IN MATRIX

$$C = \left(C_1(\underline{r}) \;\vdots\; C_2(\underline{r}) \;\vdots\; \cdots \;\vdots\; C_N(\underline{r}) \right)$$

THEN SNR IS

$$SNR_R = \frac{SNR_F}{g\sqrt{R}}$$

WHERE R IS $T_{AQ,F}/T_{AQ,R}$, ACCELERATION FACTOR

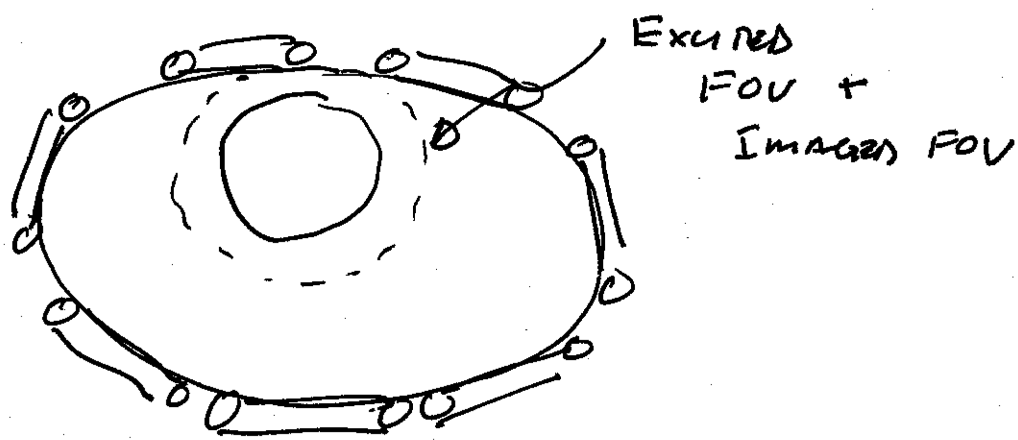
AND

$$g_m = \sqrt{\left[\left(C^* \Psi^{-1} C\right)^{-1}\right]_{m,m} \left(C^* \Psi^{-1} C\right)_{m,m}} > 1$$

FOR THE m^{th} PIXEL, Ψ IS NOISE COVARIANCE.

PARALLEL TRANSMIT

USE COIL SENSITIVITIES TO RESTRICT FOV



ONLY IMAGE OVER THIS RESTRICTED FOV

IN THIS CASE, SNR LOSS IS JUST SCAN TIME

$$SNR_R = \frac{SNR_F}{\sqrt{R}}$$

BECAUSE COILS NOT USED FOR ENCODING

g FACTOR EFFECTS REQUIRED RF POWER

HIGH g FACTOR, POORLY CONDITIONED PROBLEM

⇒ LARGE RF AMPLITUDES

COMPARISON

PARALLEL RECEIVE	PARALLEL TRANSMIT
• FULL FOV	• RESTRICTED FOV
• SNR LOSS FROM SCAN TIME REDUCTION	• SNR LOSS FROM SCAN TIME REDUCTION
• SNR LOSS FROM g FACTOR	• NO g-FACTOR SNR LOSS
• SAME RF POWER	• INCREASED RF POWER DUE TO g FACTOR

BOTH CAN BE COMBINED

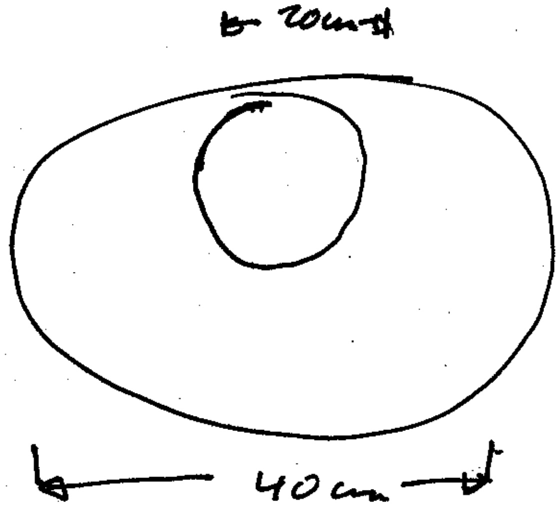
ACCELERATE BY A FACTOR OF 4 BY

2X REDUCTION IN FOV

2X PARALLEL RECEIVE ACQUISITION

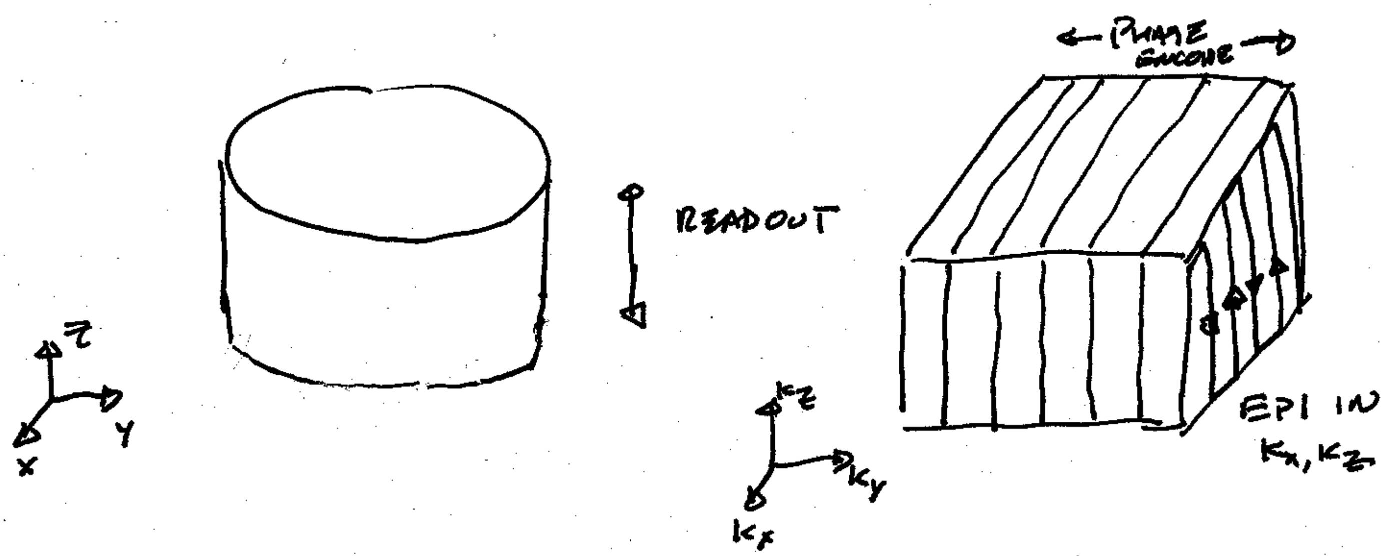
EXAMPLE APPLICATION: CARDIAC IMAGING

EXCITE ONLY 20 cm CYLINDER AROUND HEART



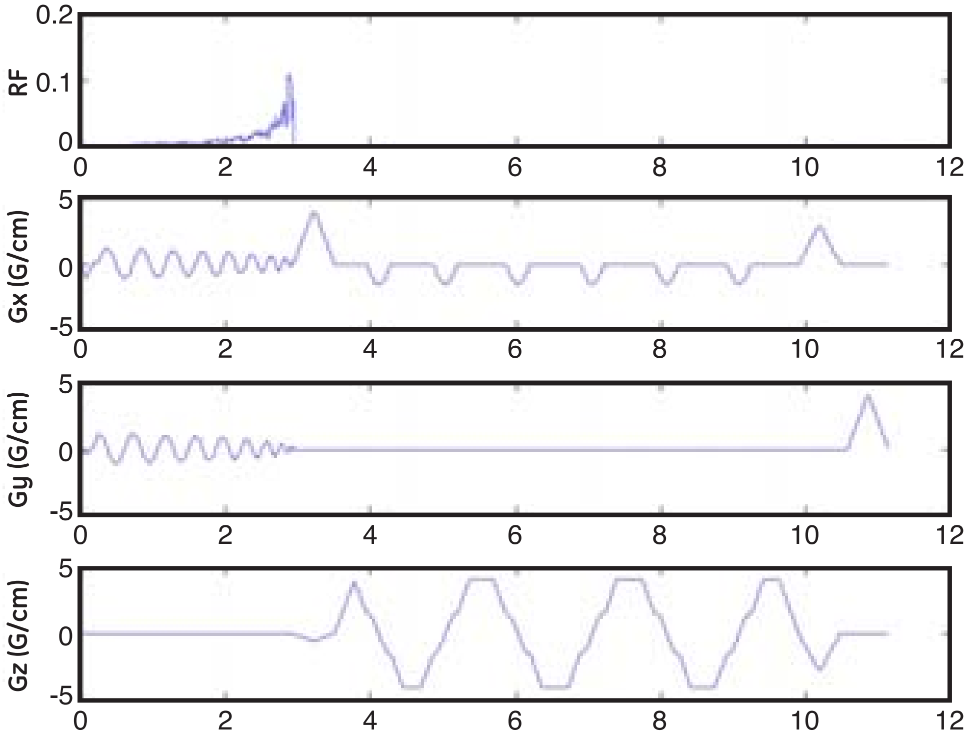
ASSUME 8 20cm COILS, SURROUNDING BODY

NEED FOV RESTRICTION IN Z, READOUT



Restricted FOV Imaging

Pulse Sequence



Excitation Profiles